

TOXIC CHEMICALS IN AGRICULTURE

RISKS TO WILD LIFE

*Report to the
Minister of Agriculture, Fisheries and Food,
and to the
Secretary of State for Scotland,
of the Working Party on
Precautionary Measures against Toxic Chemicals
used in Agriculture*

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*During the preparation of this report the
Ministry of Agriculture and Fisheries and
the Ministry of Food were amalgamated*

Report to the Minister of Agriculture, Fisheries and Food, and to the Secretary of State for Scotland, of the Working Party on Precautionary Measures against Toxic Chemicals used in Agriculture.

I. PREFACE

1. The use of chemicals to destroy pests and weeds is becoming more and more widespread, and as it increases, so too does the fear that these chemical treatments may be masking a number of undesirable, or even dangerous, side-effects. The risks run by the operatives who handle the poisons were dealt with in our first report (January, 1951),* and our recommendations on measures by which these dangers could be minimized have now been incorporated in legislation. We have also dealt, in our report to Ministers, of May, 1953,† with the possible hazards run by the person who eats food which, at an earlier stage in its production, was exposed to some toxic chemical. Here, too, steps have been taken to implement our main recommendations.

2. Our present report deals with a third set of problems—the dangers which the toxic chemicals now used in agriculture bring to the wild life, plant and animal, of our countryside. This comes last in the list of our enquiries, not because we or the authorities by whom we were appointed do not share the concern to which it gives rise, but because it was immediately apparent that the subject constitutes an extremely difficult field of enquiry. There is certainly no lack of statement about game birds and other animals dying after having fed in fields treated with toxic chemicals, and about unwanted changes in verges and hedgerows following the use of toxic sprays. The difficulty has all along been the impossibility of measuring the extent of the danger. We wish to make this clear at the outset so as to obviate any impression that the presentation of our Report implies that we have been able to give an exact scientific answer to the questions put to us. But at the same time we also wish to say that we believe that dangers do exist, and that even if they cannot be defined precisely, measures should be taken to minimize the possibility of the new toxic chemicals used in agriculture spoiling our countryside.

II. TERMS OF REFERENCE

3. We were reconstituted by the Minister of Agriculture and Fisheries and the Secretary of State for Scotland jointly in May, 1953, and were given the following revised terms of reference:

To investigate the possible risks to the natural flora and fauna of the countryside from the use in agriculture of toxic substances, including the possible harmful effects for agriculture and fisheries, and to make recommendations.

4. We took these terms of reference to mean that our task was to enquire into all available information on the subject, and that we were to consider not only the dangers to which wild animals and plants were being subjected, but also the accidental hazards which the new toxic chemicals used by farmers introduce into the lives of ordinary farm animals. We have tried to deal with insects generally, but have had to concentrate mostly on honey bees, because it is only about these that information is adequate. Indeed, when we discovered how limited was the information on which we could draw, we obtained permission to conduct a few small field experiments, so as to discover, first, whether useful information about the collateral effects of the toxic chemicals used in agriculture could be obtained in this way; and second, whether our experience justified recommending larger-scale enquiries.

* *Toxic Chemicals in Agriculture*, H.M. Stationery Office, 1951.

† *Toxic Chemicals in Agriculture (Residues in Food)*, H.M. Stationery Office, 1953.

III. COMPOSITION

5. The membership of the Working Party was as follows:

Professor S. Zuckerman, C.B., F.R.S. (Chairman)	Office of the Lord President of the Council.
Professor F. Blakemore, D.V.Sc., M.R.C.V.S., D.V.S.M.	University of Bristol Veterinary Labora- tory, Agricultural Improvement Coun- cil.
W. Morley Davies, Esq., M.A., B.Sc., F.R.I.C.	Ministry of Agriculture and Fisheries (National Agricultural Advisory Service).
Capt C. Diver, C.B., C.B.E.	Nature Conservancy.
J. W. Evans, Esq., M.A., Sc.D., D.Sc. (up to 30th September, 1954)	Ministry of Agriculture and Fisheries (Infestation Control Division).
Sir Norman Kinnear, C.B.	Nature Conservancy.
B. S. Lush, Esq., M.D., M.R.C.P.	Medical Research Council.
J. R. McCallum, Esq., M.C.	Department of Agriculture for Scotland.
P. R. C. MacFarlane, Esq., B.Sc.	Scottish Home Department (Fisheries Division).
J. K. McGirr, Esq., B.Sc., M.R.C.V.S.	Ministry of Agriculture and Fisheries (Veterinary Laboratory).
W. C. Moore, Esq., M.A.	Ministry of Agriculture and Fisheries (Plant Pathology Laboratory).
F. T. K. Pentelow, Esq., M.A.	Ministry of Agriculture and Fisheries (Fisheries Department).
Sir Edward J. Salisbury, C.B.E., Hon. L.I.D. (Edin.), D.Sc., Sec. R.S.	Ministry of Agriculture and Fisheries (Royal Botanic Gardens) Agricultural Improvement Council.
G. G. Samuel, Esq., M.Sc.	Agricultural Research Council.
I. Thomas, Esq., M.Sc., Ph.D.	Ministry of Agriculture and Fisheries (Plant Pathology Laboratory and In- festation Control Division).
H. Cole Tinsley, Esq., M.B.E.	Agricultural Improvement Council.
H. N. White, Esq.	Ministry of Agriculture and Fisheries (Infestation Control Division).

JOINT SECRETARIES

H. E. Cox, Esq. (from November, 1953 onwards)	Ministry of Agriculture and Fisheries (Infestation Control Division).
J. Wardley Smith, Esq., B.Sc.	Office of the Lord President of the Council.
D. White, Esq. (from May, 1953 to November, 1953)	Ministry of Agriculture and Fisheries.

IV. SCOPE OF THE ENQUIRY

6. We have pursued our enquiry under the following four main heads:

- Which toxic chemicals used in agriculture constitute a danger to plants and wild animals?
- In what circumstances do these dangers arise?
- Are there any precautionary measures by which these dangers can be obviated or minimised?
- Are legislative powers additional to those which already exist needed to protect flora and fauna?

V. INTRODUCTION

7. Public concern about the collateral effects of the toxic chemicals used in agriculture derives from three separate issues. The first is the fear that the accidental destruction of wild animals and plants is occurring on a wide enough scale to affect the balance of life throughout the countryside. The second is that most normal people are deeply upset when they see corpses of animals which have been accidentally killed by toxic sprays, and when they think that these treatments may have caused suffering and pain. The third is the unsightliness, temporary though it may be, of verges or hedgerows that have been accidentally, or deliberately sprayed.

8. In approaching the problem, we were fully conscious of the fact that there is no such thing as a fixed balance of nature, and equally that every advance that has occurred in the evolution of plants and animals has meant a change in this so-called balance. Man's part in transforming the face of the earth is only the most recent contribution to a process which is as ancient as life itself. It is, however, probably a more rapidly-acting and more far-reaching factor than any of those which have preceded it. As our species has multiplied, and as we have spread over the globe, forests have been laid low, and many animal species have disappeared, or their number been so considerably reduced that they now constitute little more than fragments of a previous picture of animal life. This process of change has intensified progressively over the past four centuries, and the essential question that we have had to ask ourselves is whether the chemicals now being used in farming constitute a more serious hazard to the fauna and flora of our land than did earlier innovations in farming and forestry practice. Even if the public interest in these matters is now guarded by such official organisations as the Agricultural Departments and the Nature Conservancy, we need to be assured that these new chemical pesticides do more good than harm, not only immediately, but also in the long term, before we accord them a general blessing.

9. Chemicals such as nicotine, derris and compounds of copper have been in use for many years. They are all toxic to some degree, but there is already enough experience to show that, in the way they are used at present, they do not constitute a menace to the wild life of the country. On the other hand, arsenic, in the form of arsenates and arsenites, which has also been used for a very long time, is still a source of danger, especially to bees and to farm animals which gain access to sprayed potato crops. The main danger, however, lies with the newer pesticides such as the organophosphorus compounds. The aim of the research workers, both in industry and at research stations, who devise these substances is, of course, that they should be toxic only to specific pests. But absolute specificity is difficult to obtain, because many of the chemical processes which govern the living matter of plants and animals are the same. A chemical which will kill one kind of animal is therefore likely to kill another. Hence, in spite of the laboratory tests and field trials which precede the release of a new chemical for general use, it is to be expected that unforeseen and undesirable collateral effects may come to light only during a period of full scale introduction, or after several seasons' use. The problem of deciding whether there may be undesirable long-term biological effects is, however, immensely difficult, since these have to be disentangled from those due to a variety of other factors which also influence the natural cycles of animal and plant populations.

Acreages Sprayed

10. The land surface of the United Kingdom is about 59 million acres, of which in 1952 about 18 millions were arable and 13 millions were permanent grass. In 1953 about 2.6 million acres were treated with crop-protective chemicals of which about 2 million were treated with hormone weedkillers. It has been estimated that if these treatments were to be used to the full in contributing to the expansion of agriculture, a further $2\frac{1}{2}$ million acres of farmland, including 1.6 million acres of cereals, should be treated. This would make about 5 million acres in all, or about 10 per cent of our land surface.

11. An estimate of the types and acreages of the crops actually sprayed with various chemicals in the United Kingdom in 1953 is given in Appendix A.

Lethal Properties of Chemicals used

12. Generally speaking, a pesticide which is toxic to one species of plant or animal, will be found toxic, in greater or lesser degree, to many others. But information on this point is very limited, particularly with regard to wild plants and animals.

13. Poisons may also act in different ways on the animal body. It is, therefore, difficult to compare their toxicities directly. Any comparison must also take into account the fact that some poisons are rapidly and completely eliminated from the body, in general without producing lasting damage, whereas others may persist or accumulate and give rise to harmful effects after a period. The toxicity of the acute poisons which belong to the former class is sometimes expressed in terms of the single dose which would be expected to cause death in 50 per cent of a number of animals submitted to test. When little experimental data are available, as for example for the larger animals, it is usual to state the toxicity in terms of the minimum single dose which can be expected to kill any animal of the species concerned. These doses, which are normally expressed in milligrams of the chemical per kilogram of body weight, and which are referred to as the LD 50 dose and the lethal dose respectively, may vary widely from one animal species to another. Appendix B contains a summary of lethal doses for various chemicals which we have considered, and is quoted only to give some idea of the orders of toxicity of the different chemicals mentioned.

14. The risks from acute poisons arise mainly from the possibility of animals taking large single doses, as when an animal has eaten a considerable amount of a recently treated crop. It is, of course, obvious that the amount of poison which a wild animal might consume in one period of feeding can hardly be controlled.

15. Chemicals which lead to poisoning through ingestion over a period of time, or which accumulate in the body, are often referred to as chronic poisons. As the amounts necessary to produce death from single doses of such poisons are usually very high, the risks they entail arise less from single accidental ingestions than from the continued consumption of contaminated material. The possible persistence of such chemicals on crops or other material is, therefore, important. This varies with different chemicals, according to the weather which prevails after spraying, and with other factors. Systemic insecticides are absorbed by the plant and are, therefore, not washed off by rain, and may disappear more slowly than other insecticides.

16. Poisons also differ in the extent to which they produce symptoms. If symptoms are produced rapidly and the dose necessary for their production is much below the lethal dose, the risks of fatality from accidental ingestion are relatively small. Unfortunately with certain of the poisons with which we are concerned this margin is very narrow, e.g. 10 mg/kg. body weight may have little effect, whereas 15 to 30 mg/kg. may well be lethal.

17. Bearing these generalisations in mind, the evidence which we have collected suggest the following as the main factors which in theory govern the incidence and the extent of casualties among wild birds and mammals:—

1. Chemical used and its method of application

- (i) The toxicity of the main active ingredient of the pesticide to different species ; including that caused by inhalation, by external contamination of food or drink, or by a combination of these factors.
- (ii) The influence of manufacturing impurities, wetting agents, solvents, diluents, activators and other ancillary chemicals.
- (iii) The method of application, e.g. high or low volume spraying, "mist blowing", dusting or soil treatment.
- (iv) The concentration at which the chemical is applied.
- (v) The persistence of the chemical after spraying, i.e. its chemical or physical stability after spraying, and its solubility in rain or its rate of absorption into the plant tissues.
- (vi) The possibility that vegetation that has been sprayed may be more (or less) attractive to the mammal or bird than untreated vegetation.

2. The species of animal and its habits

- (i) The numbers and species of mammals and birds frequenting the sprayed area, and their respective sensitivities to the chemical used.
- (ii) The feeding and drinking habits of the different species.
- (iii) The age, body weight and food consumption of the species.
- (iv) Movements of the species during and soon after spraying.

3. The environment

- (i) Type and abundance of pests in the treated area, and their consequent influence on other animal life.
- (ii) Features in area or crop favourable to animal life, e.g. for nesting, shelter, safety from predators, warmth, regular food and water supplies.

4. The climate and season

- (i) Season of the year, with its influence on alternative food and shelter crops, migration, hibernation, harvesting, hedge berries, farming activities.
- (ii) Weather conditions during spraying, which affect chemical persistence.
- (iii) Occurrence of drought, with resultant tendency of creatures to drink spray on vegetation or heavy dews on recently sprayed vegetation.

VI. CHEMICALS USED

18. The toxicities and uses of some of the chemicals employed are described below ; additional details will be found in Appendix B.

(i) Organo-Phosphorus Insecticides

These are complex organic phosphorus compounds some of which are systemic, that is to say they are absorbed by the plant to which they are applied and translocated in the sap, which thus becomes toxic to sucking insects. Because of their greater efficiency, these insecticides are tending to replace others that have been previously used. Unfortunately, the organo-phosphorus compounds are in the main toxic to both birds and mammals. Furthermore, they are dangerous not only when eaten, but when they are absorbed through

the skin or eyes. The majority of the compounds at present in use have an oral LD 50 dose of 1 to 25 mg/kg., although ruminants appear to be 5 to 10 times more resistant than this. The LD 50 values of malathion and similar new compounds, that have been developed for their decreased toxicity, range between 500 and 800 mg/kg.

As will be seen in Appendix A, these substances are used mostly on hops, and also on sugar beet, brassicas and strawberries. Hop spraying twice a season has become almost a routine practice. Spraying of brussels sprouts is usually undertaken only when a aphid population is actually building up, and in some years this crop may not be sprayed at all.

(ii) *Arsenical Sprays*

For many years fruit trees have been treated with sprays containing lead arsenate, and with an LD 50 dose of 5 to 50 mg/kg, these sprays are highly toxic to many animals; for example, they are very destructive to bees. There is, however, no evidence that they have at any time killed the birds which visit the orchards.

In recent years, sprays containing sodium arsenite have sometimes been used (in place of sulphuric acid or other chemicals) for the destruction of potato haulm, and to facilitate mechanical harvesting. There have been a few instances of fatalities to stock which have gained access to a sprayed crop through open gates or broken fences.

(iii) *Dinitro Weedkillers*

The dinitro compounds, dinitro-cresol (DNC or DNOC) and dinoseb (DNBP) are extensively used as selective weedkillers on cereals and peas. Their advantage is that they kill certain important weeds such as cleavers and corn poppies, which are resistant to the hormone weedkillers. The LD 50 dose of DNC for birds and rodents is about 25 to 35 mg/kg. These chemicals raise the metabolic rate of the animal and, in consequence, internal overheating may occur which, particularly in hot weather, can be fatal.

(iv) *DDT*

DDT is used very largely as a general insecticide on brassicas and peas, and on fruit of various kinds. When tested in the laboratory it is considerably less toxic to mammals and birds than are certain of the organo-phosphorus and dinitro compounds. The LD 50 dose varies from 150 to 1,000 mg/kg, depending on the animal species and the form of the DDT.

(v) *BHC*

This chemical is used very extensively on brassicas and fruit, and is about as toxic as DDT to mammals and birds. In general its effects are similar.

(vi) *Copper Compounds*

Copper compounds are used as fungicides on hops, fruit trees and potatoes. Their toxicity varies greatly for different animal species and some farm animals, e.g. sheep, can be poisoned by relatively small quantities. It follows that care must be exercised in allowing grazing animals access to herbage in orchards following copper spraying operations. A sound precaution is to await heavy rain after spraying before reintroducing the animals.

(vii) *Hormone Weedkillers*

Hormone weedkillers are selective, and are used more than any other chemical on cereals and grassland. They are only slightly toxic to birds

and mammals. The LD 50 dose of those compounds in most common use is of the order of 500 mg/kg. While the weedkillers *per se* are not dangerous, their initial growth-promoting effects may render some poisonous plants (e.g. ragwort) particularly attractive to animals for a short period, and thus lead to poisoning.

VII. SEARCH FOR EVIDENCE

19. A number of individuals and organisations submitted evidence both before and after the issue of a Press Notice in May, 1953, in which the Working Party indicated that it was anxious to hear all or any representations on the subject. Others whom it was felt could help were directly asked to submit evidence. A list of those who provided written and oral evidence is given in Appendix C. A summary is given in Appendix E of details of incidents brought to our notice in which casualties and mishaps occurred to both wild and domesticated animals. All of this evidence has been taken into account in compiling our report. We are particularly grateful for the help given by Dr. E. F. Edson.

VIII. SURVEY OF EVIDENCE

Dangers to Wild Fauna

A. MAMMALS AND BIRDS

20. For the past few years occasional deaths among game, vermin and other wild life have been reported after cornfields and orchards have been sprayed with the dinitrocresol selective weedkillers, and after carrots and peas have been treated with DDT. Public concern over these casualties came to a head with a spate of letters and articles in newspapers and periodicals in the latter half of 1952, soon after a serious outbreak of cabbage-aphid on brussels sprouts had been ended by treatment with the organo-phosphorus compound, schradan. The largest number of fatalities among birds and mammals that has been reported to us occurred during this period. In one incident, 175 corpses were found, including 19 partridges, 10 pheasants, 129 other wild birds and 7 rabbits. These incidents occurred just before the end of the harvest, and when sprouts were the only tall standing crop which could provide cover for both game and other wild mammals and birds.

21. A close review has been made of all the available information about casualties that have been reported, and it may be summarised as follows:

- (i) The total number of casualties among wild animals in an average spraying season in Britain is not high, and death from pesticides is very low compared with other causes of death (see Appendix D).
- (ii) Detailed counts of casualties in isolated incidents show that the chemicals used are not selectively toxic, and affect all species. Bodies found have included rabbits, hares, game and other types of birds, foxes, grey squirrels, rats, stoats and weasels.
- (iii) Most casualties occur within 48 hours of spraying, and practically all within four to seven days after spraying.
- (iv) When considering the sporadic nature of reports of casualties, it has to be remembered, first, that wild creatures tend to hide when sick; second, that casualties may be eaten by predators; and third, that the occurrence of casualties may not be reported. Even so, it would seem from the evidence we have had—and we have sought it widely—that the greater part of agricultural spraying brings little or no risk to wild mammals and birds.

- (v) The most dangerous treatments, in order of importance are: organophosphorus insecticides applied to brassicas in late summer; and arsenicals applied for potato haulm destruction in September. Casualties may also occur occasionally with dinitro weedkillers applied to corn and peas between March and July; and with DDT insecticides used on carrots and peas. This summarises the evidence for the period which we have investigated. It does not, however, follow that the same pattern will be produced every year, as a variety of factors will affect the way casualties will occur.
- (vi) Dinitro compounds were originally used as dyes for woollen materials, and birds and mammals which come into contact with them are stained a bright yellow. There is no evidence that in itself such staining causes death, but in certain circumstances, when the crop is tall and sprayed rather late, the dinitro compounds might produce casualties.
- (vii) Although DDT is not very toxic, casualties have been observed, particularly in dry weather, when birds feed persistently in an area which has been sprayed. Deaths may also occur among young birds, which are more susceptible, and which may be fed on grubs poisoned with DDT.
- (viii) We know of no instance of a bird or mammal being directly killed by hormone weedkillers. It should, however, be noted that many small birds, and in particular the chicks of game birds, live on insects which they collect from the woods or arable fields. If, therefore, partridges hatch out in a field which has been effectively sprayed with a hormone weedkiller, it is possible that at least some of them might die of starvation. In general this is hardly likely to be a major risk, since most birds usually build nests in edges of fields, in hedgerows and in trees, and the likelihood of adjacent fields having the same crop, and both being sprayed, is not very high.

B. INSECTS

22. The problem of the control of harmful insects by chemicals is difficult because insects and plants form a closely integrated and complex community, the destruction of any one member of which may have far-reaching effects.

23. Insect populations may be affected in two distinct ways, (a) directly by the use of insecticides designed primarily to destroy pests but incidentally also killing natural predators and parasites, as well as useful pollinating insects of which there are many besides the domesticated honey bees; and (b) indirectly by the use of herbicides. The latter may result in more profound and permanent changes than the former.

24. The danger of disturbing the balance between pest insects and their predators and parasites has long been recognised, and although the influence of plant protective chemicals on certain aspects of this problem has been the subject of intensive research, far too little attention has been given to the problem as a whole, in spite of its economic importance to cultivators.

25. Another difficulty is caused by the appearance and spread of strains of insect which are resistant to the insecticide being used. This possibility has been realised for some time, but it has become prominent since the discovery of DDT-resistant flies.

(a) *Insecticides*

26. Some of the older insecticides were more selective than the newer ones. Lead arsenate is a good example. This has no contact effect and has to be eaten to be poisonous. It is therefore completely selective against biting insects and does not kill others. But some of the newer poisons are of a contact type and are effective at very low dosages against a wide range of insects.

27. When the chemical attack upon a particular pest also results in the indiscriminate killing of many other species occupying the treated habitat, but not necessarily otherwise associated with the pest attacked (i.e. as predators

or parasites), conditions can easily be created in which the natural checks upon the populations of other species are removed. If such species happen to be resistant to the direct and indirect effects of the chemical used, their populations get out of control and may rapidly reach pest proportions. A classic example of such a change is the serious increase in fruit tree red spider mite [*Metateetranychus ulmi* (Koch)] following (i) the introduction and general use of tar oil washes in the 1920s, (ii) the use of DNC sprays in the 1930s and early 1940s, and (iii) the introduction and widespread use of DDT and BHC sprays in the years 1946-48. The tar oil washes destroyed the mosses, lichens and algae in which many beneficial insects hibernated, thus removing an essential feature of the habitat complex; the use of DNC sprays resulted in the almost complete elimination of the few important beneficial insects which still over-wintered on the trees; and the DDT and BHC sprays killed most of the remaining beneficial species. In all, some forty species that were directly or indirectly associated with the mite have been reduced or eliminated in heavily sprayed orchards. Certain of the organo-phosphorus insecticides, which are very efficient against the mite itself but are even more drastic in their action on insects generally than DDT and BHC, have aggravated rather than alleviated the problem. Many predacious insects, e.g. Mirids and Anthocorid bugs, are partially herbivorous, and are killed by these sprays. Some degree of specificity may be obtained by the use of systemic insecticides that enter the plant sap, but there is some evidence that these too may effect beneficial species. The ideal insecticide would be one that killed only the pest and none of its associates. Some of the most recently developed acaricides (mite-killers) approach this ideal, and are already being widely used in commercial orchards.

28. The problem in an orchard—a perennial crop—is not the same as that in a field of annuals. The fruit-trees and the plants beneath them form a group of permanent habitats for a number of species which, if their populations are totally destroyed, may not recolonize the treated habitat for some time. This may allow the quick build-up of a pest such as the red spider mite. But surrounding hedgerows provide what is probably a very important natural reservoir of parasites and predators, and so long as there are sufficient reservoirs, properly distributed, it would be difficult to cause permanent damage to the population of beneficial insects on perennial crops by the use of insecticides on the crops alone. It would therefore appear very unwise, in the present state of our knowledge, to interfere with the hedgerows in the vicinity of sprayed perennial crops.

29. With annual crops, grown under clean cultivation and probably forming part of a rotation, no permanent habitat is formed, and nearly all the insects found on crop plants in farms and market gardens, as well as orchards, have alternative wild host-plants. Since there is still a high proportion of the land in this country under wild plants, and since these host-plants are mostly well distributed over the countryside, spraying cultivated crops with chemicals is not likely to result in any permanent widespread changes in the number of species and in species distributions, although there may be local reductions on the sprayed areas. But such treatment may interfere with pollinating insects and cause harm by killing those that collect pollen and nectar—for example, pollen beetles may assume such pest proportions as to necessitate spraying, yet they have on occasion been shown to improve pollination of certain brassica seed crops. Hedgerows, again, may be an important reservoir of insects—predatory, parasitic and pollinating—beneficial to annual crops, and the wholesale removal of these natural reservoirs may have far-reaching results.

30. Honey bees are dealt with separately below (para. 44 et seq.).

(b) *Herbicides*

31. Some of the weedkillers now in general use may not be directly toxic to insects. They are designed to bring about changes in the plant composition of the habitats to which they are applied. They act selectively by severely reducing dicotyledenous flowering plants; by eliminating those that are most susceptible; and consequently, by favouring the increase of the unaffected monocotyledons such as cereals and grasses. By so altering the proportions of branching to straight-stemmed or closely tufted plants, the physical conditions, or "amenities", within a habitat can also be profoundly changed.

32. If certain plants are eliminated from a habitat, it will no longer be able to support populations of any insects that are specifically dependent on the presence of those plants; equally, an increase in the populations of other plants (e.g. cereals and grasses) will favour population growth among insects that are cereal and grass-dependent. It is also obvious, but less widely recognised, that changes in the vegetation structure, and consequently in the physical conditions, will bring about further considerable changes in the fauna. What is not known is how great or important to cultivators these changes may be.

In addition, the problem must be visualized in terms of the nature of the habitats treated. When used on farm or market garden crops, weedkillers will reduce the food supply, and therefore the numbers, of pollen and nectar feeding (pollinating) species visiting or living in the treated area; but probably no more so than any other method of clean cultivation. If, however, similar treatment is extended to marginal habitats, such as hedgerows, much of the value of these reservoirs is likely to be destroyed because of the secondary changes brought about in the populations of predators, parasites, and other beneficial species.

33. But insect numbers also fluctuate naturally, so that without greatly increased knowledge and precise controls we cannot safely relate effect to cause.

34. Observations on the use of DNC as a weedkiller on winter wheat, made at our request, showed a slight decrease in the numbers of insects in the air over the treated field on the day after spraying; but more elaborate experiments of longer duration would be necessary in order to detect with certainty possible differences between the populations in sprayed and unsprayed fields.

35. We have received evidence which suggests that after repeated applications, some of the more stable plant-protective chemicals may accumulate in the soil. The resultant effect on the soil fauna is a subject for research, and we are satisfied that the importance of the problem is recognised by biologists.

36. Finally, it must once again be emphasised that with the exception of work done on the fauna of fruit trees the amount of factual information available is very meagre and that the prime necessity is for more work to be done on all aspects of this subject. For example, when a new insecticide or herbicide is introduced, or an existing one is used in a different way, it is important to study carefully the effect not only on the noxious insects but on all the predators, parasites, pollinators and neutral insects and other animals involved, indeed to make an ecological survey of the "field complex".

C. FISH

37. Fish are very susceptible to contamination of the water in which they live, and some work has been done to establish the lethal doses of many commonly used chemicals. But although fish are so sensitive, the large volume of water in which they live usually precludes the possibility of their being poisoned by spray drift, or even by the accidental spraying of the water with the concentrations normally used in agriculture. It is reported from America, however, that fish mortality may be high when heavy rainfall washes insecticides from a sprayed area into streams. It is doubtful if the rainfall under British conditions would be sufficient to provide the run-off necessary to produce a toxic effect.

38. We have received no evidence that plant protective chemicals, when properly used, have affected fish either in streams or ponds. It is known, however, that considerable damage has been caused when drums which had contained concentrated chemicals had been washed out in a watercourse, or when a large volume of spray not required for a field had been allowed to run to waste.

39. We have examined the legislation pertaining to the prevention of pollution of rivers, and it is clear to us that anyone emptying surplus poisonous material or washing out containers of poisonous materials in a stream may commit an offence under one or more Acts of Parliament, and may also render himself liable to proceedings at common law.

Dangers to Domesticated Fauna

A. MAMMALS AND BIRDS

40. Some instances of losses of sheep and cattle have occurred. In one incident which occurred in 1953, 23 in-calf cows broke into a field of potatoes which had been sprayed with sodium arsenite. Fourteen of the cows died, mostly between 4 and 10 days after eating the sprayed haulm; 3 of them cast their calves before they died. In another incident in 1952, 60 sheep strayed into a field of sugar beet which had been sprayed with an organo-phosphorus compound; 49 of them died.

41. Since the movements and diet of farm animals are theoretically within the control of the owner, the risk of casualty should be negligible, and human negligence or inability to appreciate and to follow clear instruction and advice has been the cause of those accidents which have come to our notice. Negligence can consist of failure to dispose of partly emptied chemical containers; to remove contaminated soil in farmyards; to refrain from spraying when spray would drift into adjacent fields; to ensure that spraying machines are filled in the field being treated, in order to avoid spillage of spray liquid in other fields; and to maintain fences or close gates. But a contributory cause may well be the natural curiosity of animals which, simply for that reason, wander into a field where spraying is taking place, or has just taken place.

42. While the chemicals used for crop protection are approximately as toxic to domestic animals as they are to man, the method of poisoning is different. For man, the greatest risks are from continued inhalation of air-borne particles by the operator or from absorption through the skin; with animals it is from consuming food which has been contaminated by spray or spillage. Lethal doses of chemical may be ingested by farm stock from several square yards of crop sprayed at normal concentration, especially with the organo-phosphorus compounds. Thus a real responsibility rests with the individuals supervising spraying, and with the managers of livestock

in the vicinity of spraying operations. Most spraying with toxic chemicals is done on a contract basis by large companies whose employees are fully aware of the hazards to which they and animals may be exposed. Since the risks to animals arise from human negligence, it is important that all those concerned should be obliged to take the necessary precautions, remembering that farm animals may, apparently out of curiosity, wander into an area which is being sprayed.

43. In our second report we drew attention to the potential hazards to humans arising from the use of rodenticides in food stores. Apart from the rodent control operations of local authorities, servicing companies and County Agricultural Executive Committees, it is becoming a practice for farmers to put down treated baits, particularly warfarin-treated baits, to control rodents. All rodenticides are toxic, to a greater or lesser degree, to mammals and birds, which means that care must be exercised when laying baits to ensure that domestic animals will not be able to get at them. The bodies of poisoned rats should also be removed as frequently as possible, since animals eating the bodies of rats poisoned with certain rodenticides may themselves be poisoned. While it is true that modern rodenticides such as warfarin, which is an anti-coagulant, reduce the hazards to livestock as compared with those arising from most of the older rat poisons, accidental poisoning of cats, dogs and occasionally pigs, has occurred with warfarin, despite the fact that several doses need to be consumed over a period before toxic effects are produced. Larger farm animals and poultry are relatively resistant to this type of chemical, and it is very unlikely that these species could be poisoned under normal rat-baiting conditions. The advertising and labelling of rodenticides should not convey the impression that rodenticides of any kind are harmless to animals other than rats.

B. HONEY BEES

44. The average annual retail value of the honey produced by bees in this country is £1·4 million. In addition, bees play an essential part in agriculture and horticulture as pollinators.

45. The loss of honeybees because of the use of toxic chemicals in agriculture is no new problem. But arsenical sprays used to be the only lethal substances of any significance which the beekeeper had to worry about. Now we understand that losses from chemical poisoning are more than twice those occurring before the introduction of the newer crop protective chemicals. The incidence of loss appears to fall most consistently and heavily in such areas as the Holland division of Lincolnshire, where brassica seed crops are grown extensively, and where chemical weed control of cereals is commonly practised; and in parts of Cambridgeshire, where losses from arsenical poisoning have been regularly confirmed. Even if the colonies recover, sudden losses of the foraging bees in an apiary mean the loss of the honey crop for the season, and a corresponding reduction in the number of bees available as pollinators in the locality.

46. During 1948–50, thirty-two beekeepers in the Holland division of Lincolnshire were interviewed, and details of damage, if any, from sprays were noted. In that period chemical poisoning probably accounted for the complete loss of 12 colonies of bees, and severe damage to 104. DDT and BHC dusts were indicated as the cause of the majority of these losses. A similar survey in 1951 recorded 50 colonies in one apiary affected by arsenical poisoning; 15 colonies in another apiary severely affected by BHC; and less severe losses in other instances where poisoning was indicated, but not traced definitely to a specific spray or dust.

47. Sixty-three cases of suspected poisoning of bees reported to the National Agricultural Advisory Service at Rothamsted Lodge in 1948 were investigated in detail. Only 30 could be confirmed on the evidence available. These involved 189 colonies, of which 131 were damaged by arsenical compounds. Comparable losses have been confirmed annually since 1948, arsenic being responsible for a high proportion.

48. The application of toxic chemicals to open fruit blossom has been responsible for much loss, ranging from a high proportion of the workers of a colony to the slow but complete extinction of the whole colony. The spray falling on to flowering weeds under the orchard trees, and on to moist patches which the bees use as watering places, has also contributed to the loss.

49. The poisoning effects of chemicals on bees may be divided into :

- (i) the direct spray effect—the effect of spray falling on to bees at work in a crop,
- (ii) the residual effect—the effect on bees visiting a field, after the spray has dried, and of their feet coming into contact with sprayed surfaces,
- (iii) the fumigant effect—the effect on bees of the fumes of a chemical,
- (iv) the stomach effect—the effect of drinking poisoned water or nectar or of consuming poisoned pollen, and
- (v) the brood effect—the effect on the brood of being fed on poisoned food.

50. The insecticides most dangerous to bees are the arsenical type.

51. Among weedkillers, concentrated sprays containing DNC are responsible for most damage to bees. Although of relatively low toxicity as compared with DNC, the hormone weedkillers, because of their widespread use, have an important damaging effect by seriously reducing the succession of weed flowers which provide nectar and pollen. DNC and DNBP, though highly toxic to bees, do not affect them when used as winter washes in orchards, for at that time the insects are not foraging outside the hive.

52. Among the chlorinated hydrocarbon insecticides, BHC is certainly the most dangerous. Chlordane and DDT are also toxic, although the latter has not been proved in practice to be the menace it was expected to be when first introduced. Toxaphene, a member of the same group of chemicals, is reported to be safer than either BHC or DDT.

53. Among the organo-phosphorus insecticides, parathion is the most dangerous to bees ; however, it is not very widely used as a spray, so that casualties to bees from its use are not likely to be high. The systemic insecticide schradan is much less dangerous, but more widely used. It is too early yet to assess the extent of its danger to bees. It may appear unchanged in the nectar of the flowers of sprayed plants, but so far it has not been found in amounts lethal to the honey bee.

54. Lime sulphur and the copper and mercury fungicides are comparatively harmless to bees.

55. The same toxic material applied in different ways, or under different conditions, may have very different effects. In general, sprays containing oil are more dangerous to bees than those with little or no oil, while emulsions are more persistent than sprays made with wettable powders. These, in turn, are more persistent than dry dusts. High volume spraying with DDT, but not with other chemicals, tends to be less dangerous than low-volume spraying, probably because less oil stays on the bee. The danger of aerial spraying of DDT is probably due to the high oil concentration in the spray used.

56. Dusts may be very harmful quite apart from the nature of the active ingredient involved, for some of the fillers may themselves be damaging.

57. Research on the effect of crop protective chemicals on pollinating insects has been carried out at Seale Hayne Agricultural College, in collaboration with Rothamsted Experimental Station, and is being continued. Studies are being made on the effect of dusts on the lipoid water-proofing mechanism of the Hymenoptera ; on the contamination of nectar by systemic insecticides ; and on the use of repellent chemicals.

58. Bees are not the only insects which may be concerned in pollination. The pollen beetle is a pest of brassica seed crops which must often be controlled by spraying ; however, it has been found on occasion that too effective a control (95 to 100 per cent) has led to reduced yields of seeds of these crops.

59. The chemical analysis of the bodies of bees suspected of having been poisoned by toxic sprays or dusts is very difficult except in the case of arsenic. In addition, there is the physical difficulty of ensuring that the dead bees are available quickly enough to the analysts, before the chemical nature of the poison is transformed.

60. The Ministry of Agriculture, Fisheries and Food issues a Press Notice annually, appealing to fruit growers to exercise care in the application of orchard sprays, so as to protect bees. The text is reviewed each year to keep it in line with current developments in the use of new insecticides. The notice receives publicity in the farming, horticultural and beekeeping Press, and through the B.B.C. The problem is also discussed at conferences and meetings throughout the country. If we compare the losses of bees in this country with those occurring on the Continent, it is reasonable to suppose that this publicity has had a beneficial effect. It has, however, been suggested to us that the general propaganda should be further reinforced by local articles and appeals, since districts vary enormously in crops and conditions.

Dangers to Flora

61. Although much is known of the relative sensitivity of many plants to the different chemicals now in use, and though it is possible to make an estimate of the effect of the continued application of these chemicals, their cumulative effects cannot yet be judged either from experimental results or from ecological studies. With so little direct evidence to guide us, we have accordingly sought the advice of a number of eminent botanists about the possible effects of the increasing use of selective weed killers on crops and grassland. But it must be emphasised here that the possible direct effects on plants dealt with below cannot be isolated from the secondary changes these induce in the populations of animals, more particularly insects, that are intimately associated with the affected plant communities (see para. 22 *et seq.*).

62. For a cultivated crop the problem appears comparatively simple. The good farmer must get rid of weeds which reduce productivity, and the new weedkillers are frequently cheaper and more effective than machine cultivations, hand hoeing, thistle cutting and the like. The steady reduction in the weeds of cultivated crops, to which many writers have referred*, is as much the result of this technical change as it is of improvements in grain cleaning and seed dressing, which prevent these weeds from being regularly resown with the grain. Even so, not all undesirable weeds are killed by existing herbicides, and some species, such as wild oats, might be expected

* *Downs and Dunes.* SALISBURY, E. J. 1954, p. 123.

to increase, because of reduced competition with other weeds. Under any conditions the crop "community" in an arable field is highly artificial, and there are no grounds, historic or scientific, for its preservation as a plant community.

63. The problem of the plant populations of hedges, borders of fields (headlands) and roadside verges is more complicated. Here we are dealing with semi-natural communities which have been maintained in a more or less stable condition for a long time. Any radical alteration in the composition of these communities, such as might be induced by spraying with herbicides (or even by reduction of the rabbit population), would lead to a new ecological situation, and, if the treatment were maintained, to a new equilibrium. On the slight evidence available, it is difficult to forecast the nature of the new community. But a shift in the balance would be expected which would favour the grasses and lead to a reduction or elimination of some dicotyledonous species, including possibly some kinds of shrubs. These vary considerably in their degree of sensitivity. For example, creeping buttercup is more sensitive than bulbous buttercup to the action of 2-4D, and it is not outside the bounds of possibility that communities which developed under a regime of spraying might still control a fair proportion of resistant dicotyledonous species, some of which would be classified as weeds. The process might well result in the selection of resistant strains of species, the individuals of which are at present mostly susceptible to control.

64. Thus, the net result of spraying might be to produce roadside and hedgerow communities which were different from the old, but which still contained species which were undesirable both from the point of view of the agriculturist and of the road engineer, while removing many harmless and even beneficial species, such as those which contribute to the food chain of insects and birds useful to agriculture.

65. So far we have considered only the intentional spraying of fields and verges. But there is another important factor, the possible effect of the drift of spray on to uncultivated ground. Operators are generally very careful to guard against spray drifting on to an adjoining crop or garden, since they may become liable for any damage resulting from carelessness of this kind. Precautions are perhaps not as stringent when spray drifts on to common or down-land. Drift can however cause damage to susceptible species at distances of up to a mile, so that, if spraying is repeated annually, drift (e.g. on to down-land) might affect highly sensitive species and lead to their ultimate elimination.

66. Such damage is unlikely to be economically serious, except indirectly as it may affect food plants of beneficial species, since grasses are the only usable important plants on uncultivated land, and any change in the plant community is likely to be to their advantage. Spray drift on to forests or even hedgerow trees might cause damage, but is probably limited by the fear of civil action referred to above.

67. The wild flowers of the countryside are an essential part of the landscape in which we live, and there would be general and understandable resentment if they were reduced substantially by the cumulative effect of the herbicides that are now applied to grass or scrub. We must guard against any such eventuality, however unlikely it may be.

68. A number of reports have come to our notice about the effects of spray drift on areas adjacent to those under treatment. The following exceptional case will be of general interest. Tomatoes that were being grown

in glasshouses at an experimental station were all found to have been affected at a time when a strong smell of hormone weedkiller had been noticed. The two trusses which were setting at the time produced seedless hollow fruit and there was a temporary loss of vigour in the plants and a distortion in growth. No spraying had taken place nearer than one mile. While it should be stressed that tomatoes (and also rhubarb) are particularly sensitive to hormone weedkillers, this incident emphasises the potency of these chemicals, especially if applied through a low volume sprayer.

69. We were pleased to hear of the experiments carried out jointly by the Nature Conservancy and Agricultural Research Council into the effect of spraying roadside verges, and also about the long term experiment on a N.A.A.S. Experimental Husbandry Farm, where the effect of using three types of weedkillers in an arable rotation with a high percentage of cereal crops is being studied. As we have tried to indicate, we are sailing in uncharted waters, and we do not yet know precisely what shores we shall reach. Experiments of this kind are, therefore, vital.

IX. LACK OF EVIDENCE

70. Because of the anecdotal and undocumented nature of most of the information we received particularly in the early stages of our enquiry about fatalities of wild mammals and birds caused by the use of toxic chemicals in agriculture we have tried to see whether anything better could be learned from field experiments. In these necessarily short-term studies we have had the ready and full assistance of the British Agricultural Contractors Association and Rothamsted Experimental Station; and a particular responsibility was undertaken by the Nature Conservancy.

X. FIELD OBSERVATIONS

71. The investigations were of two kinds. In the first, a careful search was made of fields, immediately after they had been sprayed, in an endeavour to find the bodies of birds or animals which might have died as a result of the spraying. This investigation was carried out on a total area of 120 acres, on three fields of winter wheat in North Norfolk which had been sprayed with DNC weedkiller, and on three fields of brussels sprouts in the Evesham district of Worcestershire which had been sprayed with schradan insecticide. The second trial was more elaborate, and plots to be sprayed as well as control plots were watched by ornithologists for two days before spraying in an attempt to estimate the size of the bird population. After spraying, all the areas were searched for bodies and then the bird counting was repeated for two further days. Experiments of this kind were difficult to arrange and it was possible to carry them out on only two sites, one in Norfolk and one in Berkshire.

72. In both the DNC trials the only dead animals found were four leverets and two skylarks. Wild life was much more sparse where the schradan trial took place, and only the bodies of a yellow hammer and a thrush were found.

73. A statistical examination of the population counts made in the second DNC experiments showed that the two most common species of bird which lived and fed in the fields, larks and partridges, decreased in numbers after the area had been sprayed, but that only the decrease in the number of

larks exceeded that to be expected on the basis of normal fluctuations. Although many hares were seen, their appearance was so sporadic that statistical investigation was valueless.

74. It must not be concluded from this result that the effect of the DNC was to kill the partridges which were missing, because we believe that, had this been so, at least some of the bodies would have been picked up. It seems more likely that the chemical rendered the wheat less attractive to the birds, which, consequently moved to adjacent unsprayed areas. Similarly, the adult hares may well have moved their feeding territories, whereas the half-grown hares, which are much more likely to remain close to their form, may have eaten enough of the sprayed wheat to succumb. (Suckling hares are not likely to ingest sufficient of the chemical to be poisoned.)

75. It was intended to carry out both a field trial and field searches of brassica crops after they had been sprayed with an organo-phosphorus insecticide to kill aphids. There were, however, very few aphid attacks on brassica during the summer of 1954, and it was impossible to do more than search three fields, totalling 37 acres, which had been sprayed with schradan. These fields were in market garden areas and not particularly suitable for our purpose because the wild life population was low.

XI. THE REDUCTION OF CASUALTIES TO FAUNA

76. Slight though they were, our experiments help to confirm the picture we had built up from the anecdotal evidence. Losses do occur, but apparently only when certain conditions, which we cannot define with certainty, happen to coincide. We are obviously in no position to lay down hard and fast rules which would be certain to eliminate or substantially reduce the hazards. Certain conclusions do, however, stand out.

77. In the first instance it seems that the inhalation of lethal doses either as dust or vapour is a remote risk to wild animals. The absorption through the skin of lethal doses, even of the organo-phosphorus compounds, is also considered likely to be negligible at the concentrations used in practice, especially when the protective covering of hair or feathers is borne in mind. It follows therefore that mammals and birds die because they ingest the toxic chemicals on crops, or because they eat other creatures that have been poisoned by these chemicals.

78. Field observations show that most casualties occur immediately after spraying ; and this can be related to the fact that there is often a marked reduction after the first three or four days in the amount of the chemical remaining on or in the vegetation. Although it is true that some arsenical compounds and DDT persist and may have a cumulative effect, in practice if a creature does not absorb a lethal dose within the first few days it is unlikely to be subjected to a further dose of the same chemical in the same season. This means that if some animal which has eaten contaminated vegetation is not poisoned within a few days after spraying it is likely to survive, although it may be weakly, and therefore more liable to suffer from predators. The risk of poisoning clearly depends on the amount of chemical ingested during those first few days while the chemical persists on the vegetation.

79. It could, therefore, be argued that it should be possible to minimise casualties by spraying only in certain weather conditions. As the only object of the spraying is to kill specific pests, or unwanted plants in a

cultivated crop, spraying has, however, to be done when it will have the best practical effect. Compromise measures are clearly called for, and to get the best of both worlds the following general precautions should be considered.

(i) The chemical used should have the lowest toxicity to other forms of life compatible with the purpose for which it is used; in other words, if the weed to be killed is susceptible to hormone weedkiller, that should be used in preference to DNC. On these grounds, sulphuric acid is normally preferable to arsenical sprays for spraying potato crops, although other factors, such as availability of spraying machinery, have to be taken into account.

(ii) The chemical should be used at as low a concentration as will kill the weed or pest concerned. In general, spraying under conditions which will make the spray on the plant dry quickly will give the best pesticidal results, and at the same time reduce the risks.

(iii) Ponds and watercourses should not be sprayed, and other precautions should be taken not to spill chemicals upon the ground or to dump empty containers into ponds or watercourses.

(iv) Covers over the spray booms should be used on windy days to minimise spray drift.

80. When dinitro weedkillers are used on cereals the additional precautions that might be taken are:

(i) to spray as early in the growing season as possible before birds and mammals start using the crop for cover;

(ii) early in the season to provide artificial water points for game away from the corn.

81. Particular precautions with organo-phosphorus insecticides on brassicas are:

(i) wherever possible, flank the brassica crop with a wide strip of another crop which will be standing after the spraying period, e.g. kale, sugar beet or leys. With such alternative shelter there is less likely to be a concentration of wild life in the brassica crop;

(ii) spray as early as is economically possible so that most game and other birds will still be living in standing corn.

82. If losses of honey bees are to be reduced, there should be:

(i) greater co-operation and consultation between beekeepers, fruit growers, farmers and spraying contractors so as to bring about a better understanding of the problems of all parties,

(ii) except in special circumstances, a strict avoidance of the application of dusts and sprays to open blossom of any kind, including charlock in flower and brassica seed crops.

(iii) avoidance of drift of spray or dust on to the hedgerow flowers and on to neighbouring fields where bees are foraging,

(iv) clean cultivation or gang mowing of orchards immediately before the application of poisonous chemicals,

(v) particular care and restraint in the use of arsenical mixtures,

(vi) the use of sprays rather than dusts wherever possible,

(vii) intelligent reconnaissance by the beekeeper of his own locality, i.e. keeping watch for crops liable to be treated when being worked by bees and approaching growers about the timing of spraying, or at least arranging for warning of impending action,

(viii) evasive action by the beekeepers, i.e. moving colonies away from crops to be treated, or closing hives temporarily when crops are being sprayed.

The above precautions relate specifically to domesticated honey bees, but several of them might also reduce losses among valuable wild pollinating insects.

XII. SUMMARY

83. We have arrived at the following conclusions:

(i) The total number of casualties to wild birds and mammals that are caused by spraying during an average season in Britain is not at present high, and direct mortality from the use of toxic sprays is very low indeed compared with other causes of death. This conclusion is supported by the results of certain field trials which we initiated.

(ii) The sprays most likely to be harmful to wild birds and mammals, in order of danger are as follows:—organo-phosphorus insecticides applied to brassicas in late summer; arsenical compounds used for potato haulm destruction in September; dinitro weedkillers applied to corn and peas in Spring and July; and DDT insecticides applied to orchards, carrots and peas.

(iii) Incidents such as those reported in 1952, in which large numbers of corpses of birds and mammals were found in fields after they had been sprayed with organo-phosphorus insecticides, have not been reported in either 1953 or 1954, in spite of widely publicised requests for information. In our view, the more numerous deaths in 1952 may well have resulted from the intensity and extent of spraying which was necessary to control a severe and late attack of aphids on brussels sprouts, when there was little alternative cover for birds and mammals. The incidence of aphids on brassicas in 1953 was light, and in 1954 almost non-existent. It would therefore appear reasonable to suppose that the recurrence of incidents such as those in 1952 will be limited to years in which aphid attack is heavy and late.

(iv) Dinitro weedkillers, such as DNC and dinoseb, if used with proper care and as early as possible in the season, will not cause heavy casualties among birds and mammals.

(v) The hormone weedkillers, which are of low toxicity, require no special precautions to ensure the safety of birds. In certain circumstances, however, farm livestock may be in danger since poisonous plants such as ragwort may, for a period, become very appetising.

(vi) The arsenical sprays, although very toxic to birds and mammals, do not cause casualties when used on fruit trees; when used to kill potato haulm, special care should be taken to see that fences and gates are secure, so as to prevent farm stock straying into treated fields, and to see that spray liquid is not spilled in fields other than that being treated.

(vii) DDT is of low toxicity, but may cause casualties among birds when they feed persistently on a sprayed area, particularly in the absence of rain.

(viii) It is important that it should be realised that domestic animals and birds can be accidentally killed by spraying operations, and that both farmer and contractor should co-operate fully in the necessary precautions.

(ix) There should be suitable warnings on the containers of toxic materials about the precautions necessary when using these materials.

(x) In windy conditions, covers should be used over spray booms to minimise spray drift. This applies particularly to the spraying of hormone weedkillers and to spraying by contractors, who cannot wait for good weather conditions to the same extent as can farmers.

(xi) The danger to insects is probably much greater than that to birds and mammals and at the same time more difficult to evaluate or even to discover. We understand that the problem of the influence of plant protective chemicals on the balance of insect populations is recognised by biologists, and that it is being studied in more than one laboratory. We wish to underline the importance of this field of research.

(xii) Although the danger to honey bees is well appreciated, there has been some increase in recent years in casualties to bees following the greater use of the new crop protective chemicals. We consider, however, that improved co-operation between beekeepers, growers, farmers and spraying contractors should obviate the need for legislation to protect bees. General propaganda should be reinforced by articles in local journals or papers, and by appeals directed to local conditions.

(xiii) Provided there is no carelessness in the disposal of containers, unused spray liquids or machine washings, we are satisfied that the normal application of toxic chemicals in agriculture will not result in damage to fisheries. The existing legislation relating to the prevention of pollution of rivers should be adequate to deal with all cases of carelessness.

(xiv) The long term effect of weedkillers on the flora of the countryside is a subject about which little is known. There is no doubt that by using weedkillers the farmer is able to remove his weeds more effectively and usually more cheaply than he could by machine cultivations, handhoeing, cutting and the like, and that in both cases the resultant plant community is quite artificial. The problem of changes in the plant population of hedge-rows and roadside verges due to spraying is more complex, and is one which is of interest to biologists and road engineers as well as to farmers. In our view, long term observations of the changes are essential and we are pleased that some experiments are already in progress.

(xv) Care should be exercised by farmers in the use of rodenticides, particularly when pigs, cats and dogs may gain access to baits.

(xvi) Advertising and labelling of rodenticides should not convey the impression that rodenticides are harmless to animals other than rats.

(xvii) Finally, our enquiries have clearly shown how great are the gaps in our knowledge of the effects which the toxic chemicals used in agriculture may have on wild life, not to mention the possible consequential effects upon successful crop cultivation; and our pilot observations have indicated how well justified further field studies would be. There is a pressing need for more fundamental research.

XIII. RECOMMENDATIONS

84. We do not consider that further legislation is at present needed to deal with the subjects discussed in this report; but we recommend:

(i) That the terms of reference of the Interdepartmental Advisory Committee, set up in accordance with the recommendations of our second report, should be widened to include risks to wild life arising from the use of toxic

chemicals on pests and weeds. In this connection, the committee should be charged with the following further functions :—

- (a) to receive and consider evidence and reports of research on the risks to wild life resulting from the introduction of new chemicals ;
- (b) to bring to the notice of the appropriate bodies, when necessary, problems relating to the effect of toxic chemicals on wild life which need investigation ;
- (c) to advise on the dissemination of information ;
- (d) to advise on the framing of new legislation or regulations should such action become necessary.

The committee should include members representing nature conservation interests.

(ii) That further research and investigation, referred to in (i) (b) above might include: the effects of the main agricultural sprays on the wild life in sprayed fields, including the effect on birds of the killing of large numbers of insects ; the effects of sprays on the parasites and predators of the insect pests against which the sprays are applied ; the extent to which the killing of pollinating insects adversely affects seed-production in the sprayed crops ; the distances to which sprays of various types, such as high-volume and low-volume, may drift, and the degree of injury they may cause to adjacent or distant crops.

(iii) That the importance of adopting the precautionary measures indicated in our report be clearly made known to spraying contractors, farmers, growers and beekeepers.

Signed on behalf of the Working Party

S. ZUCKERMAN,

Chairman.

4th May, 1955.

APPENDIX A

Estimate of areas sprayed with crop protection chemicals in U.K. during 1953

								<i>Acres</i>
Organo-Phosphorus Insecticides	...	...	...	...	...	...	...
Orchard trees ...	...	...	...	...	...	...	...	negligible
Soft fruit bushes ...	...	...	...	...	...	...	...	negligible
Hops ...	...	...	...	...	...	...	...	19,000
Beans ...	...	...	...	...	...	...	...	negligible
Mangolds ...	...	...	...	...	...	...	...	negligible
Strawberries ...	...	...	...	...	...	...	...	2,000
Brassicas ...	...	...	...	...	...	...	...	2,000
Sugar Beet ...	...	...	...	...	...	...	...	3,000
Dinitro Weedkillers	...	...	...	...	...	...	...
Cereals ...	...	...	...	...	...	...	...	150,000-175,000
Peas ...	...	...	...	...	...	...	...	40,000
Beans and Lucerne ...	...	...	...	...	...	...	...	5,000
DDT	...	...	...	...	...	...	...
Brassicas and Peas ...	...	...	...	...	...	...	...	100,000
Fruit ...	...	...	...	...	...	...	...	30,000
BHC	...	...	...	...	...	...	...
Brassicas ...	...	...	...	...	...	...	...	100,000-120,000
Fruit ...	...	...	...	...	...	...	...	20,000
Lead Arsenate	...	...	...	...	...	...	...
Fruit ...	...	...	...	...	...	...	...	20,000
Sodium Arsenite	...	...	...	...	...	...	...
Potatoes ...	...	...	...	...	...	...	...	30,000
Sulphuric Acid	...	...	...	...	...	...	...
Potatoes ...	...	...	...	...	...	...	...	90,000
Cereals ...	...	...	...	...	...	...	...	10,000
Hormone Weedkillers	...	...	...	...	...	...	...
Cereals ...	...	...	...	...	...	...	...	1,750,000
Grassland ...	...	...	...	...	...	...	...	250,000
Copper Compounds ...	...	...	...	...	...	...	...	not available

APPENDIX B

Summary of Toxicity Data for Selected Plant Protective Chemicals

The figures given below have been provided by different experiments at different times and are quoted only as a guide.

Common Name	Chemical Name	Lethal Dose										
		To Mammals (mg/kg of body wt.)	To Fish (p.p.m.)									
INSECTICIDES												
A. Halogenated Hydrocarbon Compounds												
BHC (mixed isomers)...	1:2:3:4:5:6-hexachlorocyclohexane benzene hexachloride	...	...	1,000	...	...	...		
Gamma-BHC ...	Gamma-isomer of the above	...	...	330	...	...	...		
DDT ...	A complex chemical mixture, in which <i>pp'</i> -DDT predominates	...	...	...	...	...	...
<i>pp'</i> -DDT ...	1:1:1-trichloro-2:2-di(<i>p</i> -chlorophenyl)ethane	...	...	...	220 in oil; daily doses of 20-50; lethal to dogs in several weeks.	Varies with carrier	1-10		
TDE ...	1:1-bis(<i>p</i> -chlorophenyl)2:2-dichloroethane	...	...	1,000 for rats	...	...	n.a.	
Methoxychlor ...	1:1:1-trichloro-2:2-di-(methoxyphenyl)ethane	...	...	Almost non-toxic	...	...	0-2	
Dieldrin ...	Contains not less than 85% of 1:2:3:4:10:10-hexachloro-6:7-epoxy-1:4:4a:5:6:7:8:8a-octahydro-1:4:5:8-dimethanonaphthalene and not more than 15% of insecticidally active related compounds.	...	...	50-100 for rats	...	...	n.a.	
Aldrin ...	Contains not less than 95% of 1:2:3:4:10:10-hexachloro-1:4:4a:5:8:8a-hexahydro-1:4:5:8-di-methanonaphthalene and not more than 5% of insecticidally active related compounds.	...	...	40 for rats, slightly more for dogs and rabbits.	...	...	0-5	
Toxaphene ...	Chlorinated camphene (67-69% chlorine)	...	...	100-200 for rabbits and rats, 20-40 for dogs.	...	...	0-2	
Chlordane ...	2 : 3 : 4 : 6 : 7 : 10 : 10-octachloro-4 : 7 : 8 : 9-tetrahydro-4 : 7 endo-methyleneindan.	...	...	50 for rats	...	...	0-05-0-2	

Common Name	Chemical Name	Lethal Dose		
		To Mammals (mg/kg of body wt.)	To Fish (p.p.m.)	
A. Halogenated Hydrocarbon Compounds (continued)				
Heptachlor	... 1 (9) : 4 : 5 : 6 : 7 : 10 : 10-heptachloro-4 : 7 : 8 : 9(1)-tetrahydro-4 : 7-endomethyleneindene.	... 90 to rats ...	...	n.a. ...
	1 (3a) : 4 : 5 : 6 : 7 : 8 : 8-heptachloro-3a (1) : 4 : 7 : 7a-tetrahydro-4 : 7-endomethanoindene.	...	...	n.a. ...
	1 : 4 : 5 : 6 : 7 : 8 : 8-heptachloro-4 : 7-methano-3a : 4 : 7 : 7a-tetrahydroindene.	...	...	n.a. ...
DD	... 3:4:5:6:7:8:8-a-heptachlorodicyclopentadiene 1:2-dichloropropane, 1:3-dichloropropylene in approximately equal proportions.	... Toxic but odour gives warning	...	n.a. ...
B. Organo-phosphorus Compounds				
TEPP (HETP)	... Tetraethyl pyrophosphate	... 2 average to rats	...	0.25 ...
Parathion	... 0-diethyl o-p-nitrophenyl thionophosphate	... 15	...	0.2 ...
Paraoxon	... Diethyl-p-nitrophenyl-phosphate	... ...	...	n.a. ...
Malathion	... 0:0-dimethyl dithiophosphate of diethyl-mercaptosuccinate (formerly known as S-(1,2-dicarbethoxyethyl) 0:0-dimethyl dithiophosphate).	... 2	...	n.a. ...
Schradan	... Bis(dimethylamino)phosphorous anhydride or Octamethyl-pyrophosphamide.	... Greater than 1000	...	n.a. ...
Dimefox	... Bis(dimethylamino) fluorophosphine oxide	... 10	...	n.a. ...
Mipafox	... Bis(monoisopropylamino) fluorophosphine oxide	... 5	...	n.a. ...
Demeton (Systox)	... Diethylthiophosphoric ester of—ethylmercapto-ethanol	... 80-100	...	n.a. ...
EPN	... O-ethyl-o-p-nitro-phenyl benzene thiophosphate...	... 15	...	n.a. ...
		... 40	...	n.a. ...

		C. Nitrophenol Compounds											
		2-methyl-4:6-dinitrophenol ...	... ...	... ...	... ...	... ...	50 ...	... ...	... ...	... ...	... ...	... ...	n.a.
DNC ...	...	2-(1-methyl-n-propyl)-4 : 6-dinitrophenol or 2-sec-butyl-4 : 6-dinitrophenol, or 2:4-dinitro-6-sec-butylphenol.			60 to rats	... ...	... ...	... ...	... ...	... ...	... ...	... ...	n.a.
Dinoseb ...	...	2-cyclohexyl-4:5-dinitrophenol	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	n.a.
Dinex ...	...	2,4-dinitro-6-cyclohexyphenol	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	n.a.
		D. Natural Materials											
Derris ...	...	Rotenone—present in amounts 5 to 6 per cent.			... ...	... ...	... Relatively harmless ...	... ...	... ...	... ...	... ...	... ...	0.5
HERBICIDES													
2, 4, -D	...	2:4-dichlorophenoxyacetic acid	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	100
MCPA ...	...	4-chloro-2-methyl phenoxyacetic acid 2-methyl-4-chlorophenoxyacetic acid	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	n.a.
2, 4, 5-T	...	2:4:5-trichlorophenoxyacetic acid	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...	n.a.
		Note this class also includes the following (q.v.):—dinex, dinosam, dinoseb and DNC.			100 mg/kg. to dogs ...	... ...	... ...	... ...	... ...	... ...	... ...	... ...

NOTES:

(1) The toxicity figures for mammals are largely for experimental animals particularly rats. The principal sources used were *Toxic Hazards of certain Pesticides to Man*, J. M. Barnes, W.H.O. 1953 and *Guide to Chemicals used in Crop Protection*, Canada Dept. of Agriculture, December 1953.

(2) Toxicity experiments with fish are very difficult and the data can only be used to give a broad indication of the relative risks.

n.a. = not available.

APPENDIX C

I. Organisations which provided written evidence

The British Field Sports Society.
The River Boards Association.
The Scottish Landowners' Federation.
The Forestry Commission.
The Royal Society for the Prevention of Cruelty to Animals.
The Department of Scientific and Industrial Research.
The Association of British Insecticide Manufacturers.*
The Royal Forestry Society of England and Wales.
The Universities Federation for Animal Welfare.
The County Councils' Association.
The Game Keepers' Association of the United Kingdom.
The Hampshire River Board.
Pest Control Ltd.
Imperial Chemical Industries Game Division.
The Geigy Company Ltd.
The National Farmers' Union.
The British Agricultural Contractors Association.*
The Country Landowners' Association.

II. Individuals who provided written evidence

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D. S. Hendrie, Esq., B.Sc. (Agric.), B.Sc. (Est. Mangt.), Dip. Agric. (Cantab.), N.D.A.,
N.D.D., Agricultural Adviser to the U.K. High Commissioners in New Zealand.

* Organisations and individuals who gave oral evidence.

APPENDIX D

Danger to Game Birds

1. Owners of sporting estates were among the first to notice that the toxic chemicals used in agriculture can be dangerous to wild life, and in particular to game birds. Incidents to which we have referred in the main text of our report referred especially to game birds and the use of toxic sprays by farmers has often been used as an explanation for poor bags. In fact many of the reports we have received turned out to be second-hand statements of the same incidents.

2. The population of partridges and pheasants is kept high by artificial methods, and is lowered by shooting. Any increase in the heavy normal mortality of the breeding stock or of the hatched chicks due to other factors, such as toxic sprays, is of considerable importance to the game preserver, since it reduces still further the shootable surplus which is regarded as the game "crop". The game keeper's job is to keep down rats, crows, magpies, jays, etc., which destroy eggs and kill the young. The weather during the few critical weeks after hatching is also a potent factor in reducing the potential numbers of the game-bird population.

3. Under average conditions the mortality of partridges may be something as follows:—

In April, starting with 100 nesting birds (50 pairs)

May ...	... ...	750 eggs laid
May-June ...	... ...	200 eggs fail to hatch (nest losses, etc.)
June-September ...	... ...	300 chicks die before maturity
September ...	... ...	250 young survive and 80 old birds
September ...	... ...	330 total before shooting
October ...	... ...	120 crop which can be shot
September-April ...	... ...	110 normal winter "wastage" (including emigration)
April ...	... ...	100 next season's nesting stock

4. The pheasant figures are similar. If the winter is prolonged or severe then the number over-wintering may be reduced and if the hatching period is wet and cold (as in 1953) then few if any chicks are reared.

5. An estimate has been made for us of the total numbers of each species shot; this, which is based on the number of cartridges used, can only be regarded as a guide, but the figures are the only ones available on which to form any estimate of game population.

6. The estimated number shot is:—

Partridge	... ...	...	...	...	...	...	...	...	...	...	...	2½ million
Pheasant	... ...	...	...	...	...	...	...	...	...	...	...	2 million
Grouse	...	...	...	...	...	...	...	...	...	...	...	1½ million
Other game, including wild fowl, geese and ducks	...	...	...	...	...	...	...	...	...	...	...	¼ million

7. If it could be assumed that at the end of each season only the number necessary for their replacement is left then the spring population is

Partridge	... ...	...	...	...	...	...	...	...	...	...	...	2 million
Pheasant	... ...	...	...	...	...	...	...	...	...	...	...	1 million

8. In arranging for the experiments described in section IX the secretariat had many discussions with both landowners and their game keepers. It seems clear both from these conversations and from the results of the experiments that in general there is no need for these treatments with weed-killers to affect game seriously. If the cropping programme of the estate is arranged so that large numbers of adjacent fields are not given over to a single crop which is to be sprayed, the danger of starving the chicks referred to in paragraph 21 will be avoided, and if spraying of cereals and peas is carried out as early as possible in the spraying season then little loss should occur.

APPENDIX E

Summary of Detailed Reports of Incidents Involving Animal Casualties and Mishaps

Date of Spraying	Place	Crops and Area	Spray	Animal Deaths		Remarks
				Birds	Mammals	
1952	Sept. 4th and 5th Charlton Abbotts, Glos.	Brussels Sprouts, 46½ acres.	Schradaan	... 19 partridges; 10 pheasants; 129 other birds.	7 rabbits; 2 hares; 2 rats; 4 mice; 1 grey squirrel; 1 stoat.	Spraying against cabbage aphis. Drought period. Area not fully searched.
	Oct. 7th ... Guiting Power, Glos.	Brassicas, 90 acres.	Schradaan	Partridges; birds ...	Few hares; rabbits; 4 cattle very ill.	Spraying against cabbage aphis. Drought period.
Nov. 14th	n.a.	Sugar Beet ...	Schradaan	... —	49 sheep ...	60 sheep strayed into field.
Nov. 14th	n.a.	Brussels Sprouts	n.a.	53 jackdaws ...	—	
Aug. 28th and 29th	Biggleswade, Beds.	Brussels Sprouts, 28 acres.	Schradaan	... 15 partridges; 3 pheasants; 38 other birds.	2 hares; 1 rat; several mice.	
Sept. 8th...	Hitchin, Herts.	Whole Estate, 1,500 acres.	Schradaan	... —	Approximately 40 partridges; approximately 20 pheasants; approximately 220 others.	Approximately 30 hares; approximately 20 rabbits.
n.a.	Old Warden, Beds.	Corn ...	... n.a.	3 partridges; 2 pheasants; other birds.	6 hares; rabbits ...	
n.a.	Staploe, Beds.	Peas ...	... n.a.	8 adult partridges; 100's young partridges; 100's other birds.	—	

Aug. 21st and 22nd	Harlow, Essex	Sprouts, 12 acres	Schraddan	...	1 partridge; 1 crow ...	10 hares (others in extremis, 4 dis-patched).
Aug. 18th	Bolnhurst, Beds.	Sprouts n.a.	Schraddan	...	1 young partridge; 1 rook; 1 jackdaw.	1 rabbit (others seen in difficulty).
Sept. ...	Luddington, Warwicks.	n.a.	Schraddan	...	Numerous small birds	8 hares ...
Sept. ...	Hillborough, Warwicks.	n.a.	Schraddan	...	Number of pheasants, partridges and other birds.	Number of hares and rabbits.
1953	Brockenhurst, Hants.	Potato ...	Sodium Arsenite.	—	—	14 cows ...
Sept. 25th	Norfolk	Wheat, 40 acres	D.N.C.	...	4 pheasants; 1 jack-daw; 1 skylark.	... Cows broke through fence.
April 7th	...	Kale, 26 acres ...	Liquid DDT ...	...	1 leveret	... —
June 5th...	Sutton Scotney, Hants.	Brassicas	Schraddan	...	5 skylarks ...	— Crop sprayed against flea beetle.
n.a.	Bucklesham, Suffolk.	Orchard weeds...	Schraddan	...	8 partridges (small birds not searched for).	2 hares; 30 rabbits ... —
n.a.	n.a.	Potatoes	Sodium Arsenite	—	—	2 cows... ...
n.a.	N. Ireland	...	Sodium Arsenite	—	—	1 calf
1954	Norfolk	Corn	DNC	...	1 pheasant; 30 wood pigeons.	—
April 24th						Heavy chickweed growth contaminated with spray.

Date of Spraying	Place	Crops and Area	Spray	Animal Deaths			Remarks
				Birds	Mammals		
1954 June 14th	Kent ...	—	Schradan ...	—	1 Bullock ...	...	Bullock grazed around and drank at spillage in orchard through which ran pipe from mixing tank to adjacent hop yard. Hose burst, large leakage occurred.
June 15th	Somerset	... Grass	... MCPA	—	In-calf cows slipped calves—after 10 days in pasture. 1 Rabbit ...	...	Probable cause was that poisonous weeds were rendered palatable by effects of MCPA.
June 28th	Cambs.	... Carrots ...	... Schradan ...	—	Weak, inactive easily caught rabbit. Typical symptoms of scouring and lack of co-ordination.	...	
Oct. 11th	Leics.	... Grass	... DDT and/or MCPA.	—	Illness, bloody urine, lost condition and abortions in cattle.	...	Negligible trace of spray in trough water. Large quantity of sprayed spotted hemlock found. Toxic symptoms explained by effects of spotted hemlock alkaloids (conine).
Oct. 8th...	Lydd, Kent ...	Potato ...	... Sodium Arsenite	At least 6 finches	12 Bullocks ...	...	Gate left open. Cattle ate tops of self-grown turnips which had been sprayed.

Nov. 1st...	Essex...	Clover ...	...	DNC in oil solution used as defoliant prior to seed threshing.			Vague and mixed symptoms of illness in herd of 27 in-milk Friesian cattle. One cow died, others recovered.	Clover field adjacent to pasture. No signs of DNC contamination on or in cattle, or on pasture. Possible through-fence grazing but no evidence. Blood tests carried out but DNC not confirmed as cause of death and illness.
n.a.	n.a.	Potatoes	...	Sodium Arsenite	...	2 bullocks	...	Spraying machine filled in adjoining pasture and spillage occurred.
n.a.	n.a.	Potatoes	...	Sodium Arsenite	...	2 cows; 1 donkey	...	Spraying machine was taken to and from across pasture to be filled in farmyard. Spillage occurred on pasture.
n.a.	n.a.							

n.a. = not available.